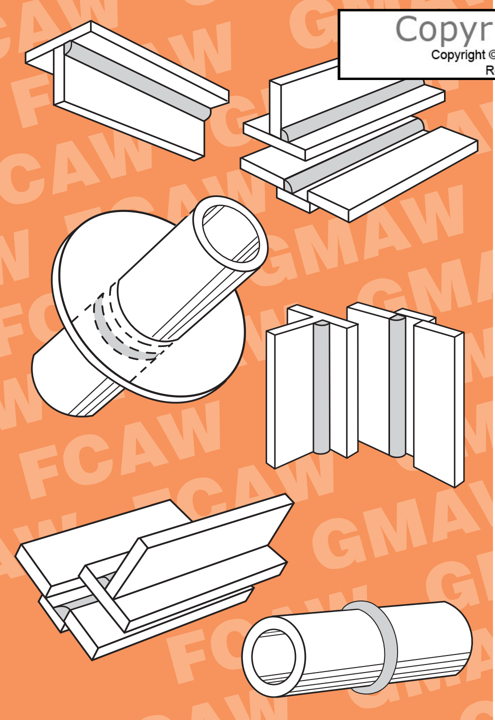

The Everyday Pocket Handbook for Gas Metal Arc Welding (GMAW) and Flux Cored Arc Welding (FCAW)

Number 4 in a series

Compiled as a useful tool for on-the-job welding personnel by the AWS Product Development Committee

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NOTE: Although care was taken in choosing and presenting the data in this guide, AWS cannot guarantee that it is error free. Further, this guide is not intended to be an exhaustive treatment of the topic and therefore may not include all available information, including with respect to safety and health issues. By publishing this guide, AWS does not insure anyone using the information it contains against any liability or injury to property or persons arising from that use.

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Basic Safety Precautions

Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpiece should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit. A separate connection is required to ground the workpiece. The workpiece should not be mistaken for a ground connection.

Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Avoid breathing the air in the fume plume directly above the arc. Do not weld in a confined area without a ventilation system. Use point-of-welding fume removal when welding galvanized steel, zinc, lead, cadmium, chromium, manganese, brass, or bronze. Do not weld on piping or containers that have held hazardous materials unless the containers have been inerted properly.

Compressed Gas Cylinders. Keep caps on cylinders when not in use. Make sure that gas cylinders are chained to a wall or other structural support.

Radiation. Arc welding may produce ultraviolet, infrared, or light radiation. Always wear protective clothing and eye protection to protect the skin and eyes from radiation. Shield others from light radiation from your welding operation.

Refer to AWS/ANSI Z49.1, *Safety in Welding and Cutting*, for additional information.

GMAW Filler Metal Specifications and Classification System

Material	Filler Metal		X Designator Description	Example
	AWS Spec.	AWS Class.*		
Steel, carbon	A5.18	ERXXS-Y EXXC-Y	Tensile strength × 1000 (psi)	ER70S-3 E70C-3
Steel, low alloy	A5.28	ERXXS-Y EXXC-Y	Tensile strength × 1000 (psi)	ER80S-B2 E80C-B2
Stainless steel	A5.9	ERXXXY	Stainless alloy (308, 410, etc.)	ER308L EC308L
Aluminum	A5.10	ERXXXX-Y	Aluminum alloy (4043, 5083, etc.)	ER4043
Nickel	A5.14	ERNiXX-Y	Major alloying elements (Cr, Fe, Mo, etc.)	ERNiCr-3
Copper	A5.7	ERCuXX-Y	Major alloying elements (Al, Ni, Si, etc.)	ERCuAl-A2
Magnesium	A5.19	ERXXYYY	Major alloying elements (Al, Zn, etc.)	ERAZ92A
Titanium	A5.16	ERTi-Y		ERTi-5

*Legend

E — Filler metal may be used as an electrode
R — Filler metal may be used as a rod
S — Solid filler metal
C — Composite or stranded filler metal
Y — Designator (or combination of designators) that describe specific alloy, shielding gas to be used, diffusible hydrogen limit, etc. Refer to the appropriate AWS Filler Metal Specification shown in table for explanation.

GMAW Shielding Gases for Spray Transfer

Metal	Shielding Gas	Thickness	Advantages
Aluminum	100% Argon	0 to 1 in. (0 to 25 mm)	Best metal transfer and arc stability, least spatter
	65% Argon + 35% Helium	1 to 3 in. (27 to 76 mm)	Higher heat input than straight argon; improved fusion characteristics with 5XXX series Al-Mg alloys
	75% Helium + 25% Argon	Over 3 in. (76 mm)	Highest heat input; minimizes porosity
Magnesium	100% Argon	—	Excellent cleaning action
Steel carbon	Argon + 3 to 5% Oxygen	—	Improves arc stability; produces a more fluid and controllable weld puddle; good coalescence and bead contour; minimizes undercutting; permits higher speeds than pure argon
	Argon + 8 to 10% Carbon Dioxide	—	High-speed mechanized welding; low-cost manual welding
Steel low-alloy	98% Argon + 2% Oxygen	—	Minimizes undercutting; provides good toughness

GMAW Shielding Gases for Spray Transfer (Continued)

Metal	Shielding Gas	Thickness	Advantages
Steel stainless	99% Argon + 1% Oxygen	—	Improves arc stability; produces a more fluid and controllable weld puddle; good coalescence and bead contour; minimizes undercutting on heavier stainless steels
	98% Argon + 2% Oxygen	—	Provides better arc stability, coalescence, and welding speed than 1 percent oxygen mixture for thinner stainless steel materials
Nickel, copper, and their alloys	100% Argon	Up to 1/8 in. (3.2 mm)	Provides good wetting; decreases fluidity of weld material
	Argon + Helium mixtures	—	Higher heat inputs of 50 and 75 percent helium mixtures offset high heat dissipation of heavier gages
Titanium	100% Argon	—	Good arc stability; minimum weld contamination; inert gas backing is required to prevent air contamination on back of weld area

GMAW Shielding Gases for Short Circuiting Transfer

Metal	Shielding Gas	Thickness	Advantages
Carbon steel	75% Argon + 25% Carbon Dioxide	Less than 1/8 in. (3.2 mm)	High welding speeds without burn-through; minimum distortion and spatter
	75% Argon + 25% Carbon Dioxide	More than 1/8 in. (3.2 mm)	Minimum spatter; clean weld appearance; good puddle control in vertical and overhead positions
	50% Argon + 50% Carbon Dioxide	—	Deeper penetration; faster welding speeds
Stainless steel	90% Helium + 7.5% Argon + 2.5% Carbon Dioxide	—	No effect on corrosion resistance; small heat-affected zone; no undercutting; minimum distortion
Low alloy steel	60 to 70% helium + 25 to 35% Argon + 4.5% Carbon Dioxide	—	Minimum reactivity; excellent toughness; excellent arc stability, wetting characteristics, and bead contour; little spatter
	75% Argon + 25% Carbon Dioxide	—	Fair toughness; excellent arc stability, wetting characteristics, and bead contour; little spatter
Aluminum, copper, magnesium, nickel, and their alloys	Argon and Argon + Helium mixtures	Over 1/8 in. (3.2 mm)	Argon satisfactory on sheet metal; argon-helium preferred base material

Globular-to-Spray Transition Currents for a Variety of Electrodes

Wire Electrode Type	Wire Electrode Diameter		Shielding Gas	Minimum Spray Arc Current, A
	in.	mm		
Mild steel	0.030	0.8	98% Argon + 2% Oxygen	150
	0.035	0.9	98% Argon + 2% Oxygen	165
	0.045	1.1	98% Argon + 2% Oxygen	220
	0.062	1.6	98% Argon + 2% Oxygen	275
Stainless steel	0.035	0.9	98% Argon + 2% Oxygen	170
	0.045	1.1	98% Argon + 2% Oxygen	225
	0.062	1.6	98% Argon + 2% Oxygen	285
Aluminum	0.030	0.8	Argon	95
	0.045	1.1	Argon	135
	0.062	1.6	Argon	180
Deoxidized copper	0.035	0.9	Argon	180
	0.045	1.1	Argon	210
	0.062	1.6	Argon	310
Silicon bronze	0.035	0.9	Argon	165
	0.045	1.1	Argon	205
	0.062	1.6	Argon	270

See page 11 for voltage settings.

Typical Arc Voltages for GMAW of Various Metals[a]

Metal	Spray[b] Globular Transfer 1/16 in. (1.6 mm) Diameter Electrode					Short Circuiting Transfer .035 in (0.9 mm) Diameter Electrode			
	Argon	Helium	25% Ar + 75% He	Ar + 1 to 5% O_2	CO_2	Argon	Ar + 1 to 5% O_2	75% Ar + 25% CO_2	CO_2
Aluminum	25	30	29	—	—	19	—	—	—
Magnesium	26	—	28	—	—	16	—	—	—
Carbon steel	—	—	—	28	30	17	18	19	20
Low alloy steel	—	—	—	28	30	17	18	19	20
Stainless steel	24	—	—	26	—	18	19	21	—
Nickel	26	30	28	—	—	22	—	—	—
Nickel-copper alloy	26	30	28	—	—	22	—	—	—
Nickel-chromium-iron alloy	26	30	28	—	—	22	—	—	—
Copper	30	36	33	—	—	24	22	—	—
Copper-nickel alloy	28	32	30	—	—	23	—	—	—
Silicon bronze	28	32	30	28	—	23	—	—	—
Aluminum bronze	28	32	30	—	—	23	—	—	—
Phosphor bronze	28	32	30	23	—	23	—	—	—

a. Plus or minus approximately ten percent. The lower voltages are normally used on light material and at low amperage; the higher voltages are used on heavy material at high amperage.

b. For the pulsed variation of spray transfer the arc voltage would be from 18 to 28 volts depending on the amperage range used.

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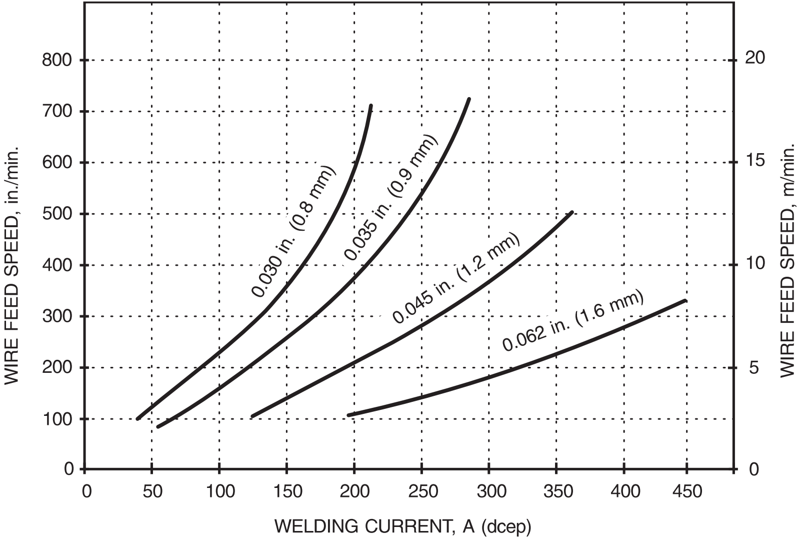

Typical Welding Currents vs. Wire Feed Speeds for Carbon Steel Electrodes

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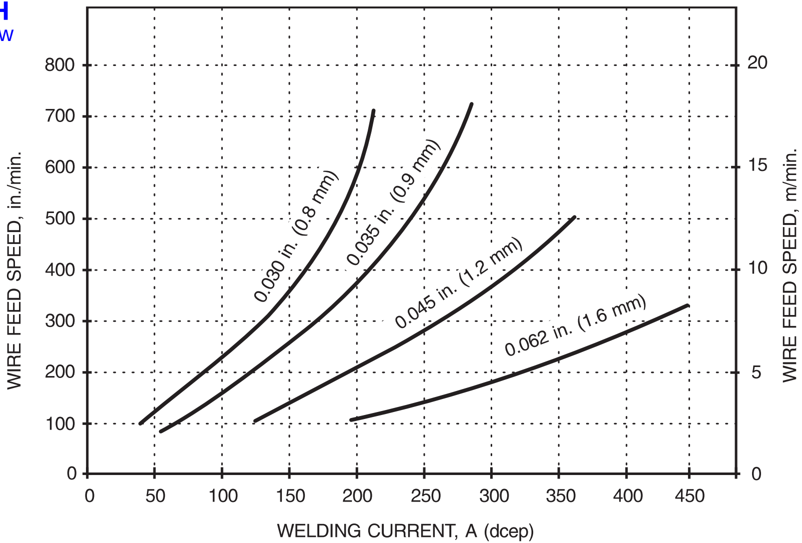
Example:
To find the melting rate for 0.045 in. carbon steel wire at a wire feed speed of 350 inches per minute, draw a line from 350 on the top scale down to the 0.045 in. curve (line); then draw a line from that intersection left to the Melting Rate scale and read 10.2 pounds per hour (lb/h).



Typical Melting Rates for Carbon Steel Electrodes

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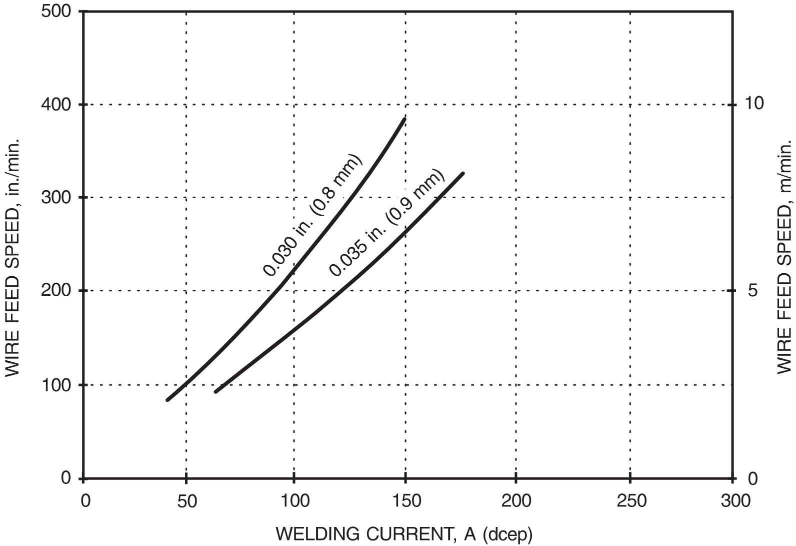

Typical Currents vs. Wire Feed Speeds Carbon Steel—Short Circuiting Arc

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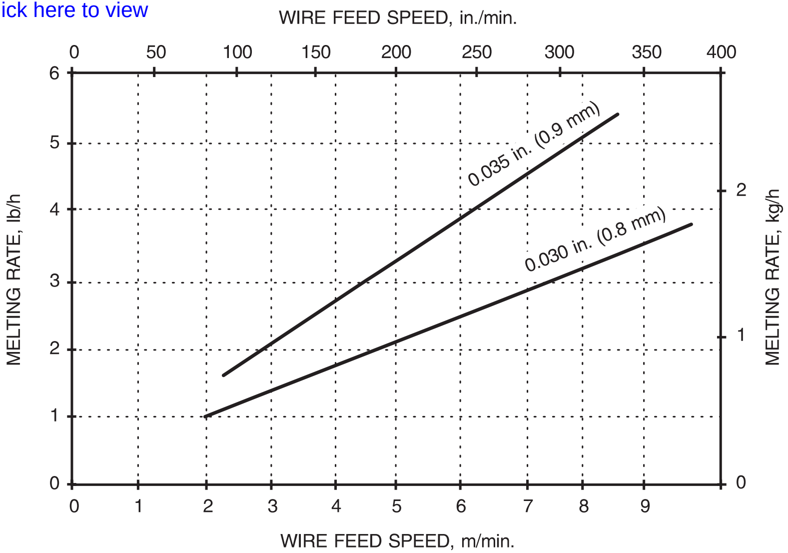

Typical Melting Rates—Carbon Steel—Short Circuiting Arc

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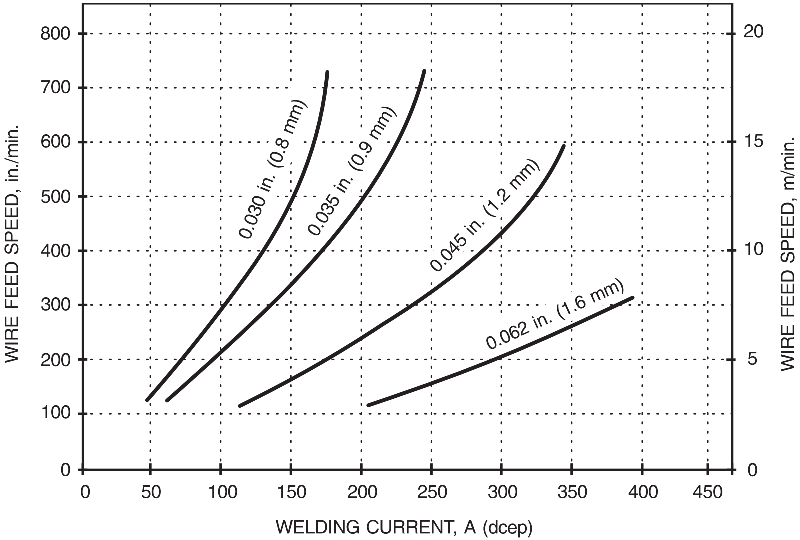

Typical Welding Currents vs. Wire Feed Speeds for 300 Series Stainless Steel Electrodes

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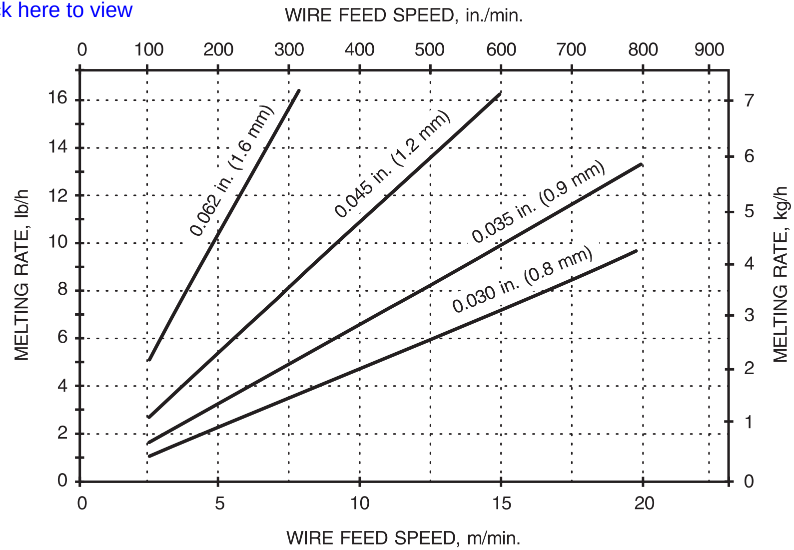

Typical Melting Rates for 300 Series Stainless Steel Electrodes

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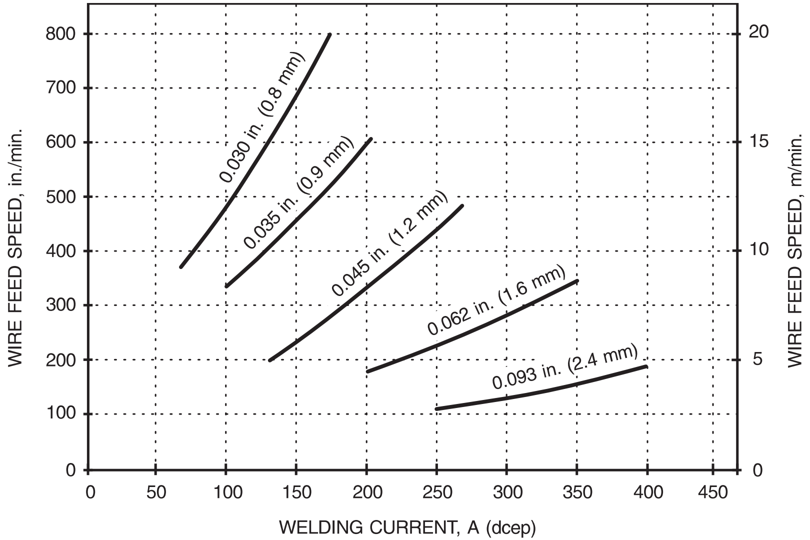

Welding Currents vs. Wire Feed Speeds for ER4043 Aluminum Electrodes

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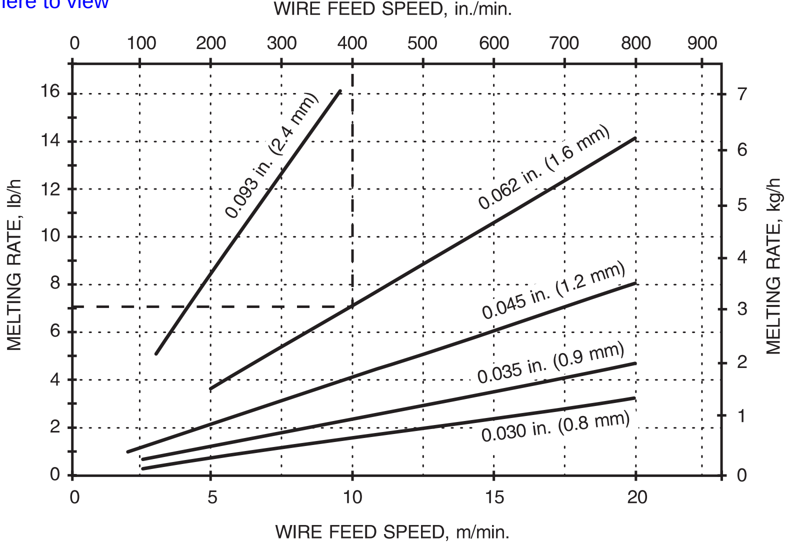

Typical Melting Rates for Aluminum Electrodes

Typical Conditions for Short Circuit GMAW of Carbon and Low Alloy Steel

Material Thickness		Type of Weld	Wire Diameter		Current Voltage[1]		Wire Feed Speed		Shielding Gas[2]	Gas Flow	
in.	mm		in.	mm	amps	volts	IPM	mm/s		CFM	LPM
.062	1.6	Butt[3]	.035	0.9	95	18	150	64	75% Ar + 25% CO_2	25	12
.125	3.2	Butt[3]	.035	0.9	140	20	250	106	75% Ar + 25% CO_2	25	12
.187	4.7	Butt[3]	.035	0.9	150	20	265	112	75% Ar + 25% CO_2	25	12
.250	6.4	Butt[3]	.035	0.9	150	21	265	112	75% Ar + 25% CO_2	25	12
.250	6.4	Butt[4]	.045	1.1	200	22	250	106	75% Ar + 25% CO_2	25	12

1. Direct current electrode positive.
2. Welding grade CO_2 may also be used.
3. Root opening of .03 in. (0.8 mm).
4. Root opening of .062 in. (1.6 mm).

Typical Conditions for GMAW of Austenitic Stainless Steel Using a Spray Arc in the Flat Position

Material Thickness		Type of Weld	Wire Diameter		Current Voltage[1]		Wire Feed Speed		Shielding Gas	Gas Flow	
in.	mm		in.	mm	amps	volts	IPM	mm/s		CFM	LPM
.125	3.2	Butt Joint with Backing	.062	1.6	225	24	130	55	98% Ar + 2% O_2	30	14
.250[2]	6.4	V-butt Joint 60ϕ Inc. Angle	.062	1.6	275	26	175	74	98% Ar + 2% O_2	35	16
.375[2]	9.5	V-butt Joint 60ϕ Inc. Angle	.062	1.6	300	28	240	102	98% Ar + 2% O_2	35	16

1. Direct current electrode positive.
2. Two passes required.

Typical Conditions for GMAW of Austenitic Stainless Steel Using a Short Circuiting Arc

Material Thickness		Type of Weld	Wire Diameter		Current Voltage[1]		Wire Feed Speed		Shielding Gas	Gas Flow	
in.	mm		in.	mm	amps	volts	IPM	mm/s		CFM	LPM
.062	1.6	Butt Joint	.030	0.8	85	21	185	78	90% He +7.5% Ar +2.5% CO_2	30	14
.093	2.4	Butt Joint	.030	0.8	105	23	230	97	90% He +7.5% Ar +2.5% CO_2	30	14
.125	3.2	Butt Joint	.030	0.8	125	24	280	118	90% He +7.5% Ar +2.5% CO_2	30	14

1. Direct current electrode positive.

Typical Conditions for GMAW of Aluminum in the Flat Position

Material Thickness		Type of Weld	Wire Diameter		Current Voltage[1]		Wire Feed Speed		Shielding Gas	Gas Flow	
in.	mm		in.	mm	amps	volts	IPM	mm/s		CFM	LPM
.062	1.6	Butt	.030	0.8	90	18	365	155	Argon	30	14
.125	3.2	Butt	.030	0.8	125	20	440	186	Argon	30	14
.187	4.8	Butt	.045	1.1	160	23	275	116	Argon	35	16
.250	6.4	Butt	.045	1.1	205	24	335	142	Argon	35	16
.375	9.5	Butt	.063	1.6	240	26	215	91	Argon	40	19

1. Direct current electrode positive.

Consumable Welding Wire—Inches per Pound of Wire

To convert from inches per pound to mm per kg, multiply by 11.52.

Wire Diameter		Material									
Decimal Inches	Fraction Inches	Mag.	Alum.	Alum. Bronze (10)%	Stainless Steel Ni + Cr.	Mild Steel	Stainless Steel Str. Chrome	Si. Bronze	Copper Nickel	Nickel	De-ox. Copper
.020		50,500	32,400	11,600	11,350	11,100	10,950	10,300	9,950	9,990	9,800
.025		34,700	22,300	7,960	7,820	7.680	7,550	7,100	6,850	6,820	6,750
.030	1/32	22,400	14,420	5,150	5,050	4,960	4,880	4,600	4,430	4,400	4,360
.035		16,500	10,600	3,780	3,720	3,650	3,590	3,380	3,260	3,240	3,200
.040		12,600	8,120	2,900	2,840	2,790	2,750	2,580	2,490	2,480	2,450
.045	3/64	9,990	6,410	2,290	2,240	2,210	2,170	2,040	1,970	1,960	1,940
.062	1/16	5,270	3,382	1,220	1,180	1,160	1,140	1,070	1,040	1,030	1,020
.078	5/64	3,300	2,120	756	742	730	718	675	650	647	640
.093	3/32	2,350	1,510	538	528	519	510	480	462	460	455
.125	1/8	1,280	825	295	289	284	279	263	253	252	249

$$\text{Melting rate (lbs/hr)} = \frac{\text{wire feed speed (in/min)} \times 60}{\text{inches per pound of wire}}$$

$$\text{Melting rate (kg/hr)} = \frac{\text{wire feed speed (mm/min)} \times 60}{\text{mm per kg of wire}}$$

FCAW Filler Metal Specifications and Classification System

Material	Filler Metal		X Designator Description	Example
	AWS Spec.	AWS Class.*		
Steel, carbon	A5.20	EXZT-Y	Tensile strength × 10,000 (psi)	E71T-1
Steel, low alloy	A5.29	EXZTY-Y	Tensile strength × 10,000 (psi)	E80T5-Ni2
Stainless steel	A5.22	EXXXTZ-Y	Stainless alloy (308, 410, etc.)	E308LT1-1

*Legend
- E — Filler metal may be used as an electrode
- T — Filler metal is tubular
- Z — Position usage
  - 0 — Flat and horizontal positions
  - 1 — All positions
- Y — Designator (or combination of designators) for usability, composition of weld deposit, shielding gas (if any) to be used, diffusible hydrogen, etc. Refer to the appropriate AWS Filler Metal Specification shown in table for explanation.

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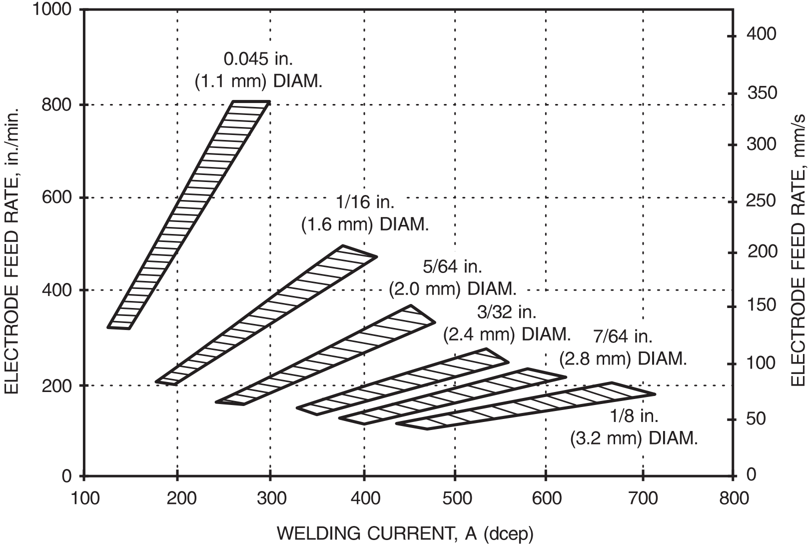

FCAW-G Electrode Feed Rates vs. Welding Current Ranges for E70T-1 Steel Electrodes with CO_2 Shielding Gas

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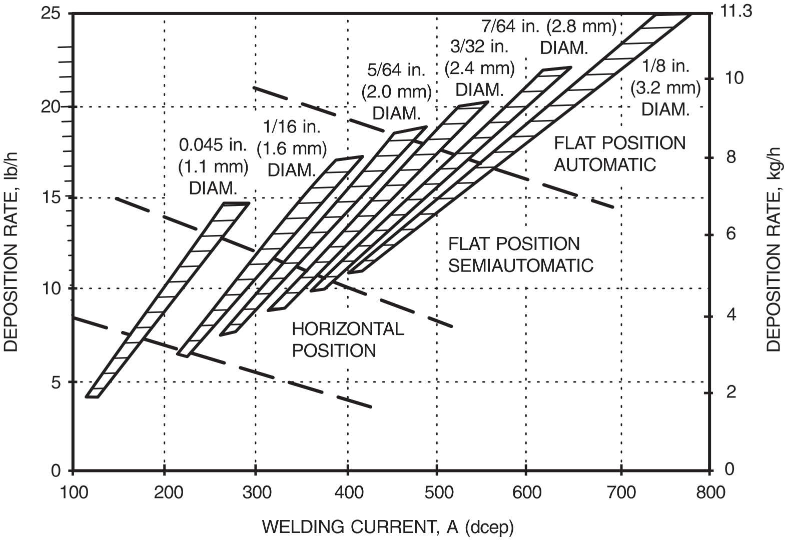

FCAW-G Deposition Rates vs. Welding Currents for E70T-1 Mild Steel Electrodes with CO_2 Shielding Gas

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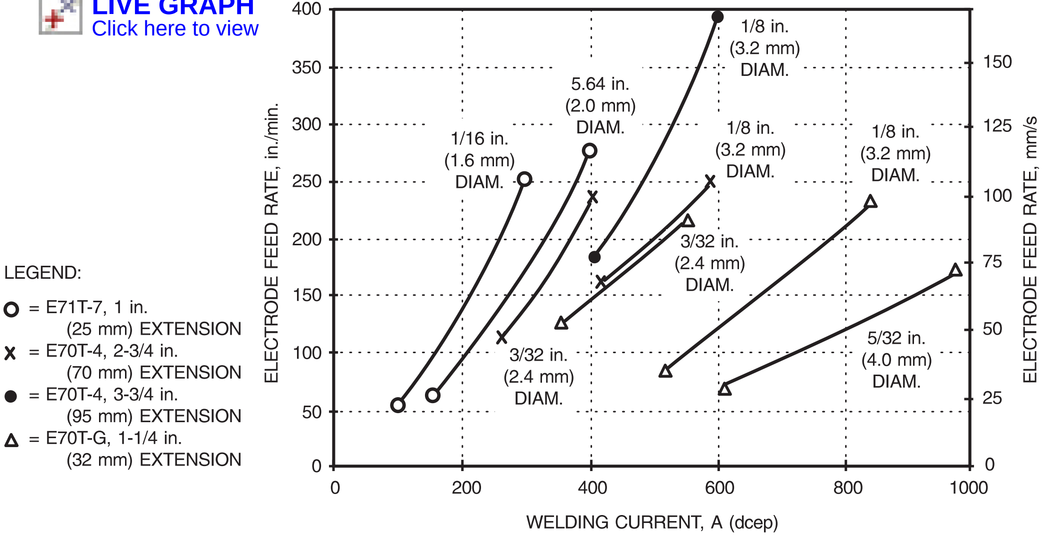

FCAW-S Electrode Feed Rates vs. Welding Currents for Self-Shielded Mild Steel Electrodes

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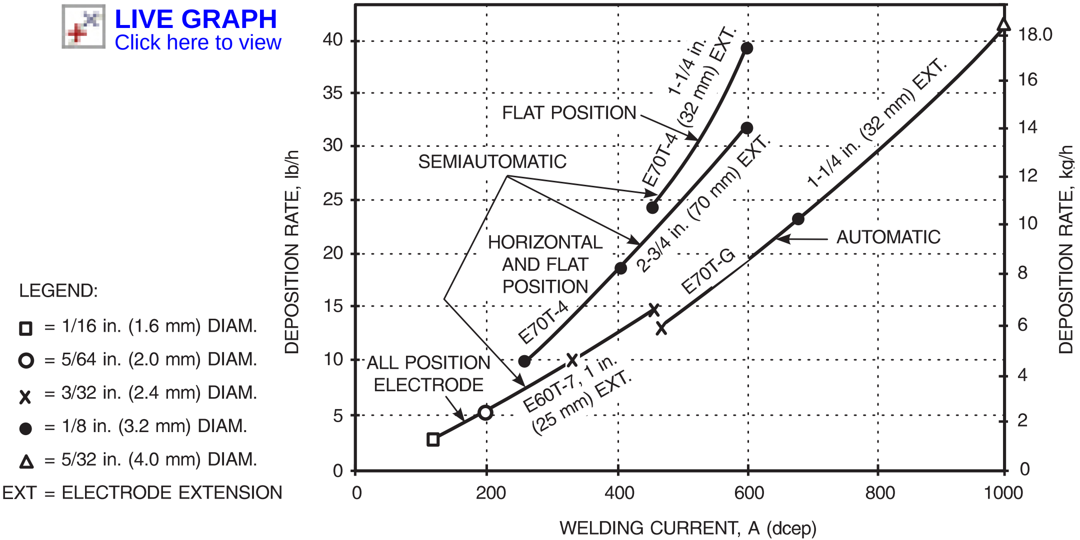
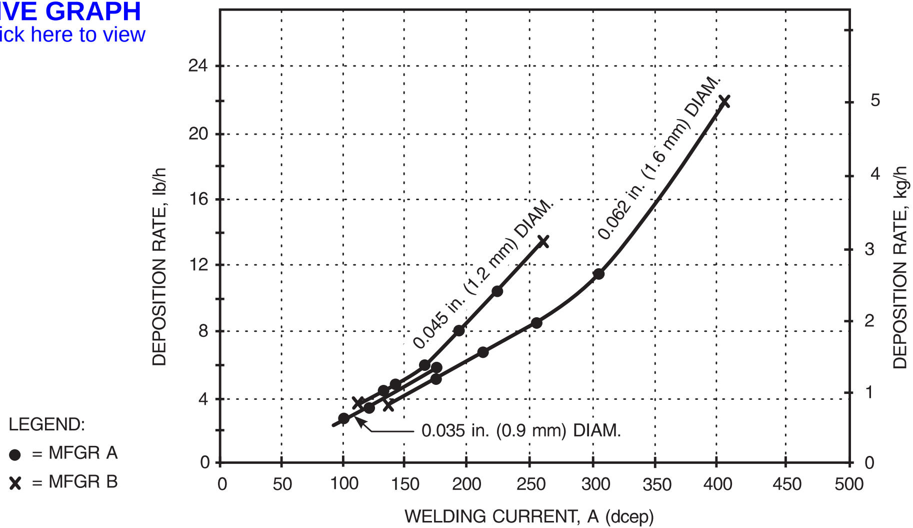


FCAW-S Deposition Rates vs. Welding Currents for Self-Shielded Mild Steel Electrodes

Deposition Rates vs. Welding Currents for CO_2 Gas-Shielded E308LT-1 FCAW-G Electrodes*

*75% Ar + 25% CO_2 shielding gas may be used and will give slightly higher deposition rates.

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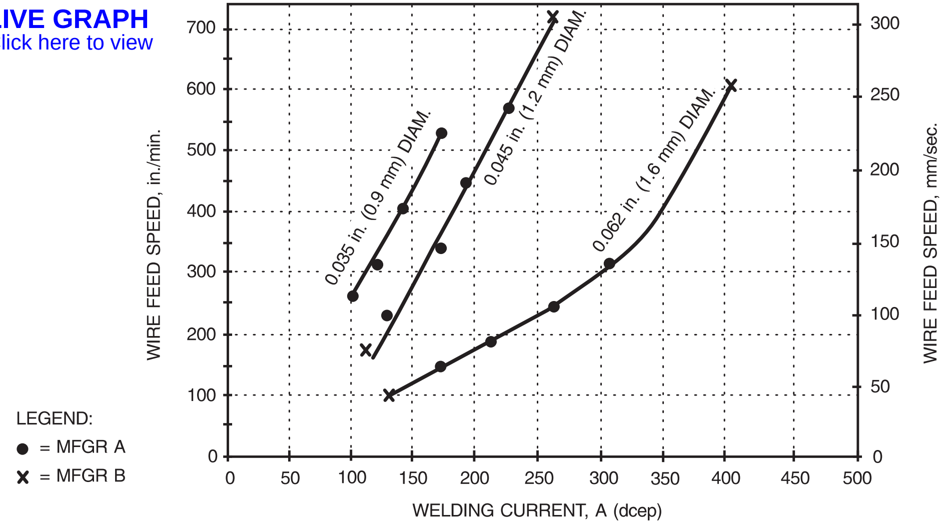


Electrode Feed Rates vs. Welding Currents for CO_2 Gas-Shielded E308LT-1 FCAW-G Electrodes*

*75% Ar + 25% CO_2 shielding gas may be used and will give the same electrode feed rate.

Typical Gas-Shielded Flux Cored Arc Welding Procedures for Carbon and Low Alloy Steel Electrodes (EXXT-1 Types)

Joint Design	Thickness, T		Root Opening, R		Total Passes	Electrode Diameter		Welding Power, dcrp (ep)		Wire Feed Speed	
	in.	mm	in.	mm		in.	mm	V	A	in./min	mm/s
Flat position groove welds (semiautomatic)											
Square butt w/backup	1/4 1/2	6 13	1/8 1/4	3 6	1 2	5/64 3/32	2.0 2.4	30 32	425 450	275 195	116 80
60° Single vee w/backup	1/2 1	13 25	0 0	0 0	2 6	3/32 3/32	2.4 2.4	30 32	480 480	225 225	95 95
30° Single vee w/backup	5/8 1	16 25	3/16 3/16	5 5	3 6	3/32 3.32	2.4 2.4	32 32	480 480	225 225	95 95
60° Double vee	1 2	25 51	0 0	0 0	6 14	3/32 3/32	2.4 2.4	32 32	450 450	195 195	80 80
45° Double bevel	1 2	25 51	0 0	0 0	4 10	3/32 3/32	2.4 2.4	32 32	450 450	195 195	80 80

Typical Gas-Shielded Flux Cored Arc Welding Procedures for Carbon and Low Alloy Steel Electrodes (EXXT-1 Types) (Continued)

Joint Design	Thickness, T		Root Opening, R		Total Passes	Electrode Diameter		Welding Power, dcrp (ep)		Wire Feed Speed	
	in.	mm	in.	mm		in.	mm	V	A	in./min	mm/s
Horizontal position groove welds (semiautomatic)											
45° Single bevel w/backup	1/2	13	1/8	3	6	5/64	2.0	28	350	175	75
	1	25	1/8	3	18	5/64	2.0	28	350	175	75
Vertical position groove welds (semiautomatic)											
60° Single bevel w/backup	3/8	10	0	0	2	1/16	1.6	23	220	165	70
	1/2	13	0	0	3	1/16	1.6	23	220	165	70

Typical Self-Shielded Flux Cored Arc Welding Procedures for Carbon and Low Alloy Steel Electrodes

Joint Design	Plate Thickness, T		Root Opening, R		Total Passes	Electrode Diameter		Welding Power, dc		Wire Feed Speed		Electrode Extension	
	in.	mm	in.	mm		in.	mm	A	V(P)[a]	in./min	mm/s	in.	mm
Flat position groove welds (semiautomatic)													
Square butt w/backup	0.14 3/8	3.4 10	5/32 3/8	4 10	1 2	3/32[b] 1/8[b]	2.4 3.2	300 500	29+ 33+	150 200	65 85	2-3/4 2-3/4	70 70
60° Single vee w/backup	1/2 1	13 25	3/8 3/8	10 10	3 6	1/8[b] 1/8[b]	3.2 3.2	500 550	32+ 36+	200 300	85 125	2-3/4 3-3/4	70 95
60° Double vee	1/2 3	13 76	3/32 3/32	2 2	2 26	3/32[b] 1/8[b]	2.4 3.2	350 550	29+ 36+	190 300	80 125	2-3/4 2-3/4	70 95
Flat/horizontal fillet	5/16 1	8 25	0 0	0 0	1 4	3/32[b] 1/8[b]	2.4 3.2	350 580	30+ 27+	190 330	80 140	2-3/4 3-3/4	70 95

a. (P) — polarity: + electrode positive, – electrode negative
b. E70T-4 electrode

Typical Self-Shielded Flux Cored Arc Welding Procedures for Carbon and Low Alloy Steel Electrodes (Continued)

Joint Design	Plate Thickness, T		Root Opening, R		Total Passes	Electrode Diameter		Welding Power, dc		Wire Feed Speed		Electrode Extension	
	in.	mm	in.	mm		in.	mm	A	V(P)[a]	in./min	mm/s	in.	mm
Horizontal position groove weld (semiautomatic)													
45° Single bevel w/backup	5/16	8	3/16	5	3	3/32[b]	2.4	300	28+	150	65	2-3/4	70
	1-1/4	32	3/16	5	16	1/8[b]	3.2	400	29+	160	70	2-3/4	70
Vertical position groove welds (semiautomatic)													
60° Single vee w/backup	3/8	10	3/16	5	2	1/16[c]	1.6	170	19–	105	45	1	25
	1	25	3/16	5	6	5/64[c]	2.0	190	19–	110	45	1	25

a. (P) — polarity: + electrode positive, – electrode negative
b. E70T-4 electrode
c. E70T-7 electrode

Typical Gas-Shielded Flux Cored Arc Welding Procedures for Stainless Steels Using Stainless Steel Electrodes

Joint Design	Weld Size, T		Root Opening, R		Total Passes	Electrode Diameter		Welding Power, dcrp (ep)		Wire Feed Speed		Electrode Extension	
	in.	mm	in.	mm		in.	mm	A	V	in./min	mm/s	in.	mm
Flat position groove welds (semiautomatic)													
45° Single vee w/ backup	1/4 3/8	6 10	1/8 1/8	3 3	1 2	1/16 1/16	1.6 1.6	300 300	27–29 27–29	320 320	140 140	1/2–3/4 1/2–3/4	12–18 12–18
30° Single vee w/ backup	1/2 3/4	13 19	3/16 3/16	5 5	2 4	1/16 1/16	1.6 1.6	300 300	27–29 27–29	320 320	140 140	1/2–3/4 1/2–3/4	12–18 12–18
20° Single vee w/ backup	7/8 1-1/4	22 32	3/8 3/8	10 10	6 8	1/16 1/16	1.6 1.6	300 300	27–29 27–29	320 320	140 140	1/2–3/4 1/2–3/4	12–18 12–18
45° Double vee	1/2 3	13 76	1/8 1/8	3 3	2 25	1/16 1/16	1.6 1.6	300 300	27–29 27–29	320 320	140 140	1/2–3/4 1/2–3/4	12–18 12–18

Typical Gas-Shielded Flux Cored Arc Welding Procedures for Stainless Steels Using Stainless Steel Electrodes (Continued)

Joint Design	Weld Size, T		Root Opening, R		Total Passes	Electrode Diameter		Welding Power, dcrp (ep)		Wire Feed Speed		Electrode Extension	
	in.	mm	in.	mm		in.	mm	A	V	in./min	mm/s	in.	mm
30° Single bevel w/backup	3/8 1-1/4	10 32	3/8 3/8	10 10	3 8	1/16 1/16	1.6 1.6	300 300	27–29 27–29	320 320	140 140	1/2–3/4 1/2–3/4	12–18 12–18
Flat fillet weld	3/8 3/4	10 19	0 0	0 0	1 3	1/16 1/16	1.6 1.6	300 300	27–29 27–29	320 320	140 140	1/2–3/4 1/2–3/4	12–18 12–18
Horizontal fillet weld	1/8 3/8	3 10	0 0	0 0	1 1	.045 1/16	1.2 1.6	185 300	26–28 27–29	440 320	190 140	1/2 1/2–3/4	13 12–18

Troubleshooting Mechanical Problems Encountered in GMAW and FCAW-G

Problem	Possible Cause	Remedy
Irregular wire feed and burnback	Insufficient drive roll pressure Contact tube plugged or worn Kinked electrode wire Coiled gun cable Conduit liner dirty or worn Conduit too long	Adjust Clean or replace Cut out, replace spool Straighten cables, hang the wire feeder Clean or replace Shorten or use push-pull drive system
Electrode wire wraps around drive roll ("birdnesting")	Excessive feed roll pressure Incorrect conduit liner or contact tip Misaligned drive rolls or wire guides Restriction in gun or gun cable	Adjust Match liner and contact tip to electrode size Check and align properly Remove restriction
Heavily oxidized weld deposit	Air/water leaks in gun and cables Restricted shield gas flow	Check for leaks and repair or replace as necessary Check and clean nozzle
Electrode wire stops feeding while welding	Excess or insufficient drive roll pressure Wire drive rolls misaligned or worn Liner or contact tube plugged	Adjust Realign and/or replace Clean or replace
Wire feeds but no gas flows	Gas cylinder is empty Gas cylinder valve closed Flow meter not adjusted Restriction in gas line or nozzle	Replace and purge lines before welding Open cylinder valve Adjust to give flow specified in the procedure Check and clean

Troubleshooting Mechanical Problems Encountered in GMAW and FCAW-G (Continued)

Problem	Possible Cause	Remedy
Porosity in the weld bead	Failed gas valve solenoid Gas cylinder valve closed Insufficient shielding gas flow Leaks in gas supply lines (including the gun)	Repair or replace Turn valve on Check for restrictions in gas line or nozzle and correct Check for leaks (especially at connections) and correct
Wire feed motor operates but wire does not feed	Insufficient drive roll pressure Incorrect wire feed rolls Excessive pressure on wire spool brake Restriction in the conduit liner or gun Incorrect liner or contact tube	Adjust Match feed rolls to wire size and type Decrease brake pressure Check liner and contact tip Clean and/or replace Check and replace with correct size
Welding gun overheats	Pinched or clogged coolant line Low coolant level in pump reservoir Water pump not functioning correctly	Check and correct Check and add coolant as necessary Check and repair or replace

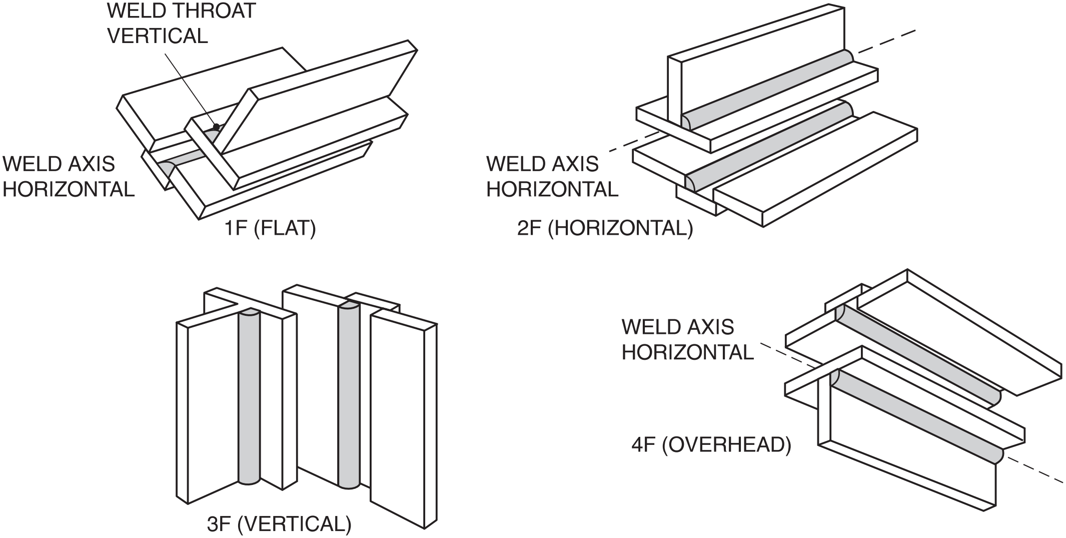
Troubleshooting Electrical Problems Encountered in GMAW and FCAW-G

Problem	Possible Cause	Remedy
Difficult arc starting	Wrong polarity Poor work lead connection	Check polarity; reverse leads if necessary Secure work lead connection
Irregular wire feed and burnback	Power circuit fluctuations Polarity wrong	Check line voltage Check polarity; reverse leads if necessary
Welding cables overheating	Cables are too small or too long Cable connections loose	Check current carrying requirements—replace or shorten if necessary Tighten
No wire feed speed control	Broken or loose wires in control circuit Bad P.C. board in governor	Check and repair if necessary Replace P.C. board
Unstable arc	Cable connections are loose	Tighten connections
Electrode won't feed	Control circuit fuse blown Fuse blown in power source Defective gun trigger switch or broken wire leads Drive motor burned out	Replace fuse Replace fuse Check connections; replace switch Check and replace

Troubleshooting Electrical Problems Encountered in GMAW and FCAW-G (Continued)

Problem	Possible Cause	Remedy
Wire feeds but no gas flows	Failure of gas valve solenoid Loose or broken wires to gas valve solenoid	Replace Check and repair if necessary
Electrode wire feeds but is not energized (no arc)	Poor workpiece connection Loose cable connections Primary contactor coil or points defective Contactor control leads broken	Tighten if loose; clean work of paint, rust, etc. Tighten Repair or replace Repair or replace
Porosity in weld	Loose or broken wires to gas solenoid valve	Repair or replace

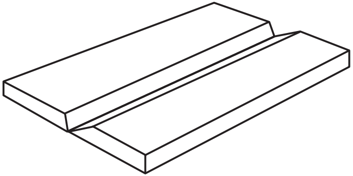
Welding Positions—Fillet (plate)



Welding Positions—Groove (plate)

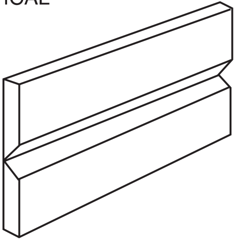
PLATES HORIZONTAL

1G

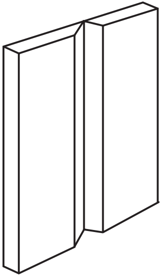


PLATES VERTICAL

2G



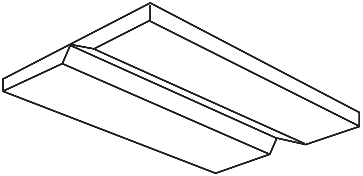
3G



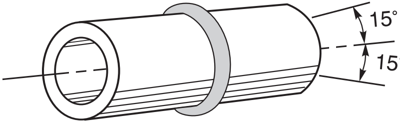
PLATES VERTICAL

PLATES HORIZONTAL

4G



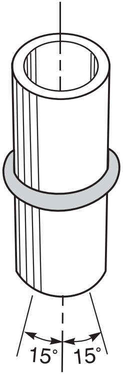
Welding Positions—Pipe



PIPE HORIZONTAL, ROTATED.
WELD FLAT (±15°). DEPOSIT
FILLER METAL AT OR NEAR THE TOP.

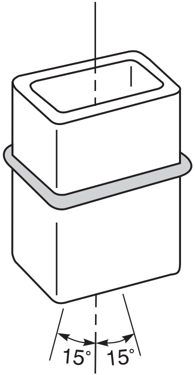
1G ROTATED

2G



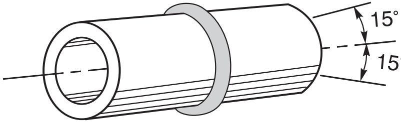
PIPE OR TUBE VERTICAL; NOT
ROTATED DURING WELDING.
WELD HORIZONTAL (±15°).

2G

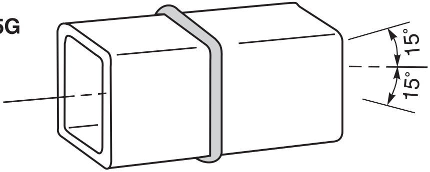


Welding Positions—Pipe (Continued)

5G

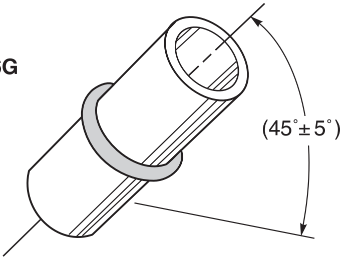


5G



PIPE OR TUBE HORIZONTAL (±15˚); NOT ROTATED DURING WELDING. WELD FLAT, VERTICAL, OVERHEAD.

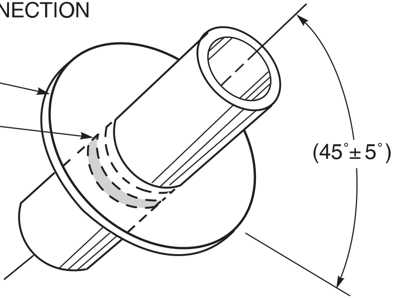
6G



6GR; T, K, Y CONNECTION

RESTRICTION RING

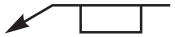
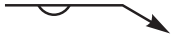
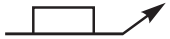
TEST WELD



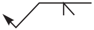
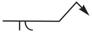
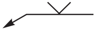
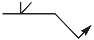
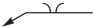
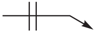
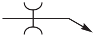
PIPE INCLINED FIXED (45˚±5˚); NOT ROTATED DURING WELDING.

Basic Welding Symbols and Their Location Significance

Refer to AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*, for more information.

Location Significance	Fillet	Plug or Slot	Spot or Projection	Stud	Seam	Back or Backing	Surfacing	Flange Corner	Flange Edge
Arrow Side									
Other Side				Not Used			Not Used		
Both Sides		Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used
No Arrow Side or Other Side Significance	Not Used	Not Used		Not Used		Not Used	Not Used	Not Used	Not Used

Basic Welding Symbols and Their Location Significance (Continued)

Location Significance	Groove							Scarf for Brazed Joint
	Square	V	Bevel	U	J	Flare-V	Flare-Bevel	
Arrow Side								
Other Side								
Both Sides								
No Arrow Side or Other Side Significance		Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used

Location of Elements of a Welding Symbol